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AEROSPACE TECHNOLOGY DIRECTORATE

POWER TECHNOLOGY DIVISION



Lewis Research Center

SUMMARY OF NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM ACTIVITIES

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1993 NASA AEROSPACE BATTERY WORKSHOP
MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

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NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM OBJECTIVES

The NASA Aerospace Flight Battery Systems Program represents a unified NASA wide effort with the overall objective of providing NASA with the policy and posture which will increase the safety, performance, and reliability of space power systems. The specific objectives of the program are listed on the facing page.

In late 1991, the NASA Administrator formed a Battery Review Board to investigate recent problems experienced with flight programs. The recommendations of the Battery Review Board were presented at the 1992 NASA Battery Workshop. Those recommendations impacted the NASA Aerospace Flight Battery Systems Program in a variety of ways. In the past year several tasks under the NASA Aerospace Flight Battery Systems Program have been redirected as a result of the Battery Review Board investigation. While the major objectives of the program remain unchanged, the approach has been modified to reflect the current recommendations.



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PROGRAM OBJECTIVES

ENHANCE CELL/BATTERY SAFETY AND RELIABILITY

MAINTAIN CURRENT BATTERY TECHNOLOGY

INCREASE FUNDAMENTAL UNDERSTANDING OF PRIMARY AND SECONDARY CELLS

PROVIDE A MEANS TO BRING FORTH ADVANCED TECHNOLOGY FOR FLIGHT USE

ASSIST FLIGHT PROGRAMS IN MINIMIZING BATTERY TECHNOLOGY RELATED FLIGHT RISKS

ENSURE THAT SAFE, RELIABLE BATTERIES ARE AVAILABLE FOR NASA'S FUTURE MISSIONS

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM - APPROACH

The approach to achieving the program objectives involves:

- 1) increasing the fundamental understanding of primary and secondary cells;
- 2) providing for improved cell/battery manufacturing process control, specifically in the area of secondary nickel-cadmium and nickel-hydrogen batteries;
- 3) opening and maintaining communication lines within NASA and the aerospace community;
- 4) providing for qualification of new technologies as they become available; and
- 5) implementing checks and balances for the verification of various cell technologies.



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APPROACH

ESTABLISH SPECIFICATIONS, DESIGN AND OPERATIONAL
GUIDELINES FOR PRIMARY AND SECONDARY CELLS AND
BATTERIES

PROVIDE IMPROVED PROCESS CONTROL

OPEN AND MAINTAIN COMMUNICATION LINES WITHIN NASA
AND THE AEROSPACE COMMUNITY

PROVIDE FOR QUALIFICATION OF NEW TECHNOLOGIES

IMPLEMENT INDEPENDENT CHECKS AND BALANCES FOR CELL
VERIFICATIONS

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM ORGANIZATION

This program is designed to enhance the safety, reliability, and performance of NASA's aerospace primary and secondary batteries as well as battery power systems. The NASA Aerospace Flight Battery Systems Program is organized under four major tasks: Program Management, Battery Systems Technology, Secondary Battery Technology, and Primary Battery Technology. The NASA Lewis Research Center (LeRC) has the overall responsibility for management of the program. Dr. Patricia O'Donnell of the Lewis Research Center is the program manager. The overall objectives, guidelines and funding are provided by NASA Headquarters through Code Q, the Office of Safety and Mission Quality. Mr. Shahid Habib is the Headquarters, Code Q program manager.



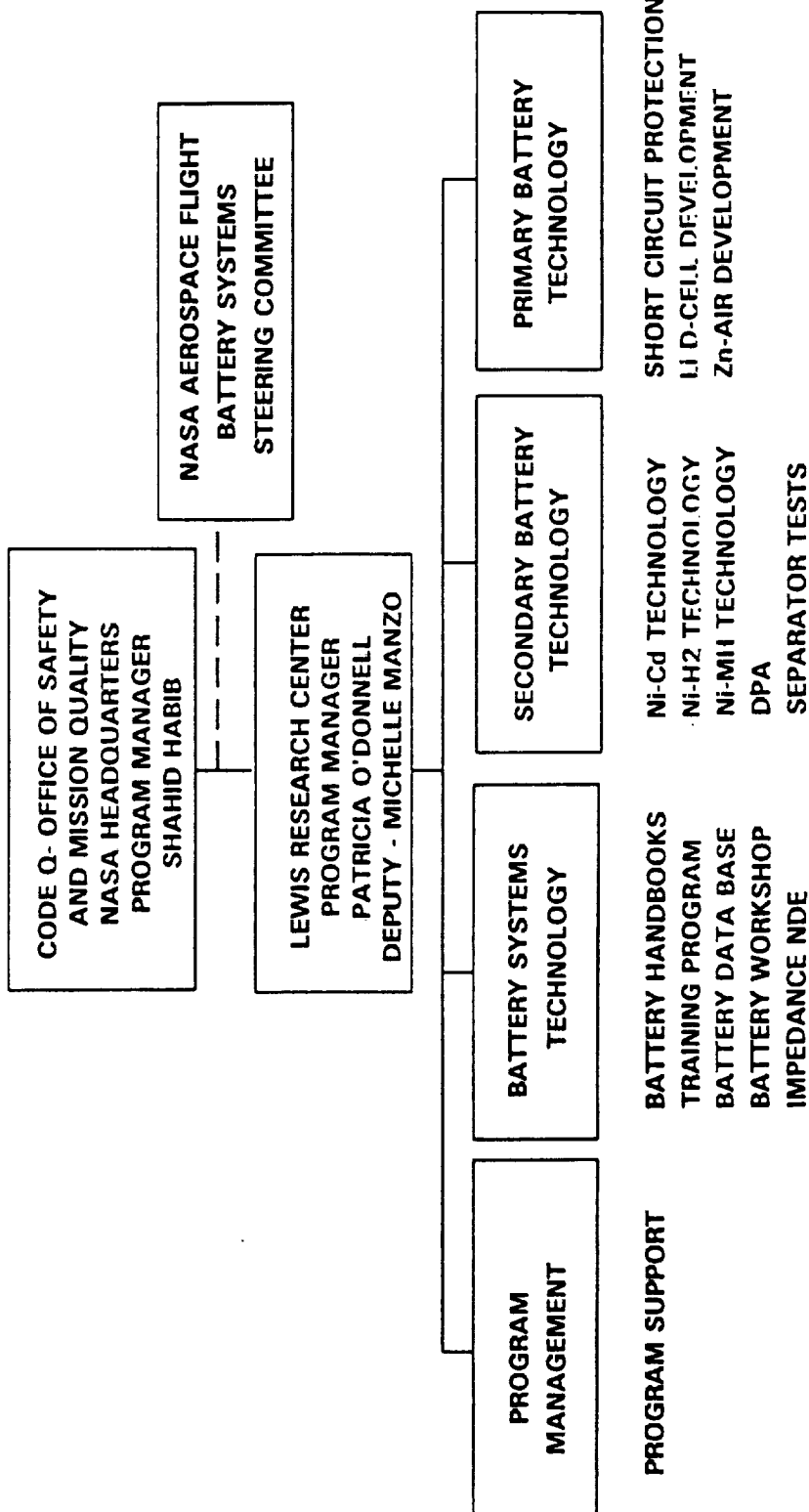
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NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM ORGANIZATION

The majority of the NASA centers are involved in the execution of specific tasks within the program. The Lewis Research Center Program Manager has full responsibility for technical management, cost and scheduling of the program. The NASA Lewis Research Center Program Manager also provides continuing coordination with all the NASA centers, Jet Propulsion Laboratory (JPL), NASA Headquarters and the NASA Aerospace Flight Battery Systems Steering Committee.

The NASA Aerospace Flight Battery Systems Steering Committee provides advice on battery issues. The Committee is chaired by the Office of Safety and Mission Quality, membership is comprised of one representative from each of the NASA centers and one representative from Aerospace Corporation, representing the Air Force.



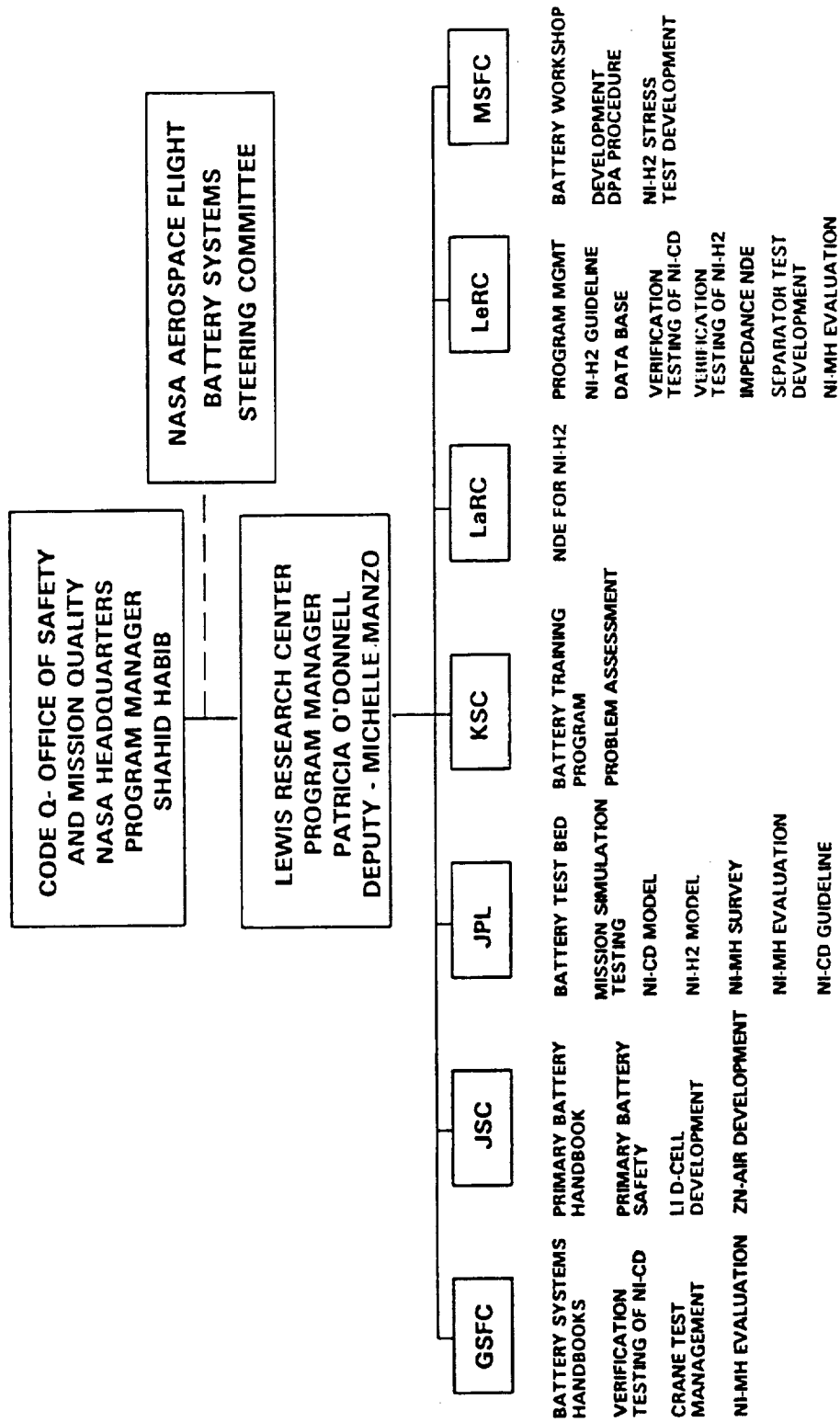
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NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM

BATTERY SYSTEMS TECHNOLOGY

The Battery Systems Technology Task addresses the overall systems aspects associated with the integration of cells into batteries and batteries into power systems. The objective is to improve the reliability of energy storage, space power system design, integration, and checkout.



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BATTERY SYSTEMS TECHNOLOGY TASK OBJECTIVE

**TO IMPROVE RELIABILITY OF ENERGY STORAGE SPACE POWER
SYSTEM DESIGN, INTEGRATION, AND CHECKOUT**

**SYSTEMS ASPECTS - INTEGRATION OF CELLS INTO BATTERIES
AND BATTERIES INTO POWER SYSTEMS**

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM



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BATTERY SYSTEMS TECHNOLOGY TASK

NASA BATTERY HANDBOOKS

BATTERY TRAINING PROGRAM

BATTERY DATA BASE

NASA BATTERY WORKSHOP

IMPEDANCE NDE

RUSSIAN BATTERY TECHNOLOGY ASSESSMENT

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM



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NASA BATTERY HANDBOOKS

OBJECTIVE: DEFINE GOOD CONSISTENT PRACTICES FOR THE DESIGN, INTEGRATION AND CHECKOUT, AND TESTING OF PRIMARY AND SECONDARY BATTERY SYSTEMS. PROVIDE GUIDELINES AND REQUIREMENTS TO ENSURE MISSION SUCCESS

NASA HANDBOOK FOR NICKEL-HYDROGEN BATTERIES
HANDBOOK FOR HANDLING AND STORAGE OF NICKEL-CADMIUM BATTERIES

REVISION OF NHB8073.1 - "NASA SPECIFICATIONS FOR MANUFACTURING AND PERFORMANCE REQUIREMENTS OF NASA STANDARD AEROSPACE NICKEL-CADMIUM CELLS" TO A GUIDELINES DOCUMENT

PREPARATION OF A GUIDELINES DOCUMENT FOR NICKEL-HYDROGEN CELLS

PRIMARY BATTERY DESIGN AND SAFETY HANDBOOK

BATTERY SYSTEMS TECHNOLOGY TASK

NICKEL-HYDROGEN BATTERY HANDBOOK

The Goddard Space Flight Center (GSFC), contracted with Mr. Jim Dunlop for the development of a NASA Handbook for Nickel-Hydrogen Batteries. The handbook has been completed and was published in September of this year. The NASA Handbook for Nickel-Hydrogen Batteries addresses the following subjects: 1) Nickel-Hydrogen Cell Design, 2) Aerospace Applications of Nickel-Hydrogen Batteries, 3) Nickel-Hydrogen Battery Design, 4) Advanced Battery Design Concepts, 5) Performance of Nickel-Hydrogen Batteries 6) Battery Procurement, 7) Standard Test Procedures for NASA, 8) Storage and Handling, and 9) Safety.



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NASA BATTERY HANDBOOKS

NASA HANDBOOK FOR NICKEL-HYDROGEN BATTERIES - GSFC

PUBLISHED - SEPTEMBER 1993, JIM DUNLOP - AUTHOR

NICKEL-HYDROGEN CELL DESIGN

AEROSPACE APPLICATIONS OF NICKEL-HYDROGEN BATTERIES

NICKEL-HYDROGEN BATTERY DESIGN

ADVANCED BATTERY DESIGN CONCEPTS

PERFORMANCE OF NICKEL-HYDROGEN BATTERIES

STORAGE AND HANDLING

STANDARD TEST PROCEDURES FOR NASA

BATTERY PROCUREMENT

SAFETY

BATTERY SYSTEMS TECHNOLOGY TASK

NICKEL-CADMIUM BATTERY HANDBOOK

As a part of the Handbook Development Task of the Battery Program, GSFC is also preparing a Handbook for the Handling and Storage of Aerospace Nickel-Cadmium Batteries. This handbook is not intended to duplicate the information covered in NASA reference Publication 1052, Sealed-Cell Nickel-Cadmium Battery Applications Manual. The purpose of this handbook is to update the handling procedures and practices for working with nickel-cadmium batteries. The Handbook covers changes in guidelines resulting from improvements in design, manufacturing, and testing of nickel-cadmium cells and batteries. The heritage of many GSFC flight Ni-Cd battery developments over the past three decades is covered in the handbook. This handbook specifically covers the following 1) Background, 2) Nickel-Cadmium Cell Primer, 3) The Environment and Nickel-Cadmium Batteries, 4) Battery Handling and Storage Guidelines and 5) Nickel-Cadmium Cell Design and Evolution (from 1960-1989).



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NASA BATTERY HANDBOOKS

**HANDBOOK FOR HANDLING AND STORAGE OF AEROSPACE
NICKEL-CADMIUM BATTERIES - LESSONS LEARNED - GSFC**

TO BE PUBLISHED BY END OF 1993 - FLOYD FORD - AUTHOR

**UPDATE HANDLING PROCEDURES AND PRACTICES FOR NICKEL-
CADMIUM BATTERIES**

BACKGROUND

NICKEL-CADMIUM CELL PRIMER

THE ENVIRONMENT AND NICKEL-CADMIUM BATTERIES

BATTERY HANDLING AND STORAGE GUIDELINES

**NICKEL-CADMIUM CELL DESIGN AND EVOLUTION - A HISTORICAL
PERSPECTIVE**

BATTERY SYSTEMS TECHNOLOGY TASK

NICKEL-CADMIUM/NICKEL-HYDROGEN GUIDELINES DOCUMENTS

As a result of recommendations made by the Battery Review Board, NASA has dropped the standard Ni-Cd cell designation. The defining document for the specification of NASA standard Ni-Cd cells, NHB 8073.1, NASA Specification for Manufacturing and Performance Requirements of NASA Standard Aerospace Nickel-Cadmium Cells is being revised into a guidelines type document. JPL is responsible for the Ni-Cd guidelines document. A similar guidelines type document for Nickel-hydrogen batteries is also being prepared under the direction of the Lewis Research Center.



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NASA BATTERY HANDBOOKS

NICKEL-CADMIUM GUIDELINES DOCUMENT - JPL

***DOCUMENT TO SERVE AS GUIDELINE AND CHECKLIST FOR THE
PROCUREMENT OF Ni-Cd CELLS FOR FLIGHT PROJECTS***

***ENCOMPASS STANDARD AND ADVANCED Ni-Cd CELL
TECHNOLOGIES***

RATIONALE FOR TECHNICAL SPECIFICATIONS

***REPRESENTATIVE VALUES AND RANGES FOR CRITICAL DESIGN
PARAMETERS***

NICKEL-HYDROGEN GUIDELINES DOCUMENT - LeRC

FOLLOW OUTLINE OF Ni-Cd GUIDELINES DOCUMENT

BATTERY SYSTEMS TECHNOLOGY TASK

PRIMARY BATTERY DESIGN AND SAFETY HANDBOOK

A Primary Battery Design and Safety Handbook has been prepared and is expected to be published in the near future. It is intended that the handbook provide National Space Transportation System users with the necessary guidelines, standard testing procedures and requirements to ensure mission success.



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NASA BATTERY HANDBOOKS

PRIMARY BATTERY DESIGN AND SAFETY HANDBOOK - JSC

***HANDBOOK TO PROVIDE NATIONAL SPACE TRANSPORTATION
SYSTEM USERS WITH THE NECESSARY GUIDELINES AND STANDARD
TESTING PROCEDURES TO ENSURE MISSION SUCCESS***

PUBLICATION EXPECTED BY END OF THE CALENDAR YEAR

BATTERY SYSTEMS TECHNOLOGY TASK

NASA BATTERY TRAINING PROGRAM

The handbooks are intended to serve as the basis for a training plan, at the engineer and technician levels, that will ensure that personnel involved with the test and operations of batteries and their related power systems are fully qualified to implement safe and proper operational procedures including storage practices. The Kennedy Space Center (KSC) has responsibility for this task. A subcommittee consisting of engineers who have direct flight battery expertise has been formed at KSC. The subcommittee is in the process of assessing battery training requirements first at KSC then within the agency. Safety and handling procedures used by individual projects are being assembled. Presently, safety and handling procedures have been mission specific. This task will attempt to develop an integrated plan to be used agency wide.



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NASA BATTERY TRAINING PROGRAM - KSC

OBJECTIVE: DEFINE TRAINING NEEDS AND TRAINING PLAN FOR
QUALIFICATION OF PERSONS INVOLVED WITH TEST AND
OPERATION OF BATTERIES

TRAINING NEEDS UNDER INVESTIGATION

DEFINE REQUIREMENTS - ASSESSMENT OF TRAINING NEEDS AT KSC
FOLLOWED BY AGENCY-WIDE ASSESSMENT OF TRAINING NEEDS

EVALUATION OF VARIOUS TRAINING PROGRAMS IS UNDERWAY

BATTERY SYSTEMS TECHNOLOGY TASK

BATTERY DATA BASE

The Battery Data Base subtask addresses a NASA Battery System Data Base Environment to serve the NASA battery community for the dissemination of technical notes, policy documentation and test data. Efforts are underway to develop a battery specific data base that would provide access to operational cycle test data in addition to a problem reporting system. The Lewis Research Center has the responsibility for the implementation this subtask.

The majority of the NASA cell test data base resides at the Naval Weapons Support Center, Crane, IN. The Crane data has been organized and structured into a battery test data base. As part of this subtask, Crane has updated NASA pack history files dating back to 1975, provided pack record structure information, and converted data tapes to a useable format for all NASA tests dating back to 1981. On-line access of the data has been established.

The Battery Review Board recommended expansion of data base to include flight data as well as ground test data. A survey has been initiated by JPL to scope the effort, evaluate the availability of flight data outside of the agency, and to define the resources required to establish such a data base.



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BATTERY DATA BASE - LeRC

OBJECTIVE: DEVELOP DATA BASE FOR THE DISSEMINATION OF TECHNICAL NOTES, POLICY DOCUMENTATION AND TEST DATA

ENDORSED BY BATTERY REVIEW BOARD

DATA BASE IS FUNCTIONAL - OPERATION HAS BEEN DEMONSTRATED

OPERATIONAL CYCLE TEST DATA - 75% OF POST 1990 DATA FROM CRANE TESTING HAS BEEN ENTERED INTO THE DATA BASE

BATTERY PROGRAM FUNDS SUPPORT MARTIN MARIETTA TESTING - DATA AVAILABLE FOR DATA BASE

EVALUATE EXPANSION OF DATA BASE ACTIVITIES TO INCLUDE INDUSTRY GROUND TEST DATA AND FLIGHT DATA - JPL SURVEY

BATTERY SYSTEMS TECHNOLOGY TASK

NASA BATTERY WORKSHOP

The NASA Battery Workshop comes under the sponsorship of the NASA Aerospace Battery Systems Program. Previously held at NASA Goddard, the Marshall Space Flight Center has hosted yearly Workshops since December 1990. The workshop serves as a forum for open communication of battery related activities between industry and government.



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NASA BATTERY WORKSHOP - MSFC

OBJECTIVE: PROVIDE FORUM FOR OPEN COMMUNICATION OF
BATTERY RELATED ACTIVITIES

WORKSHOP ADDRESSES TECHNOLOGY STATUS OF ESTABLISHED AND
EMERGING TECHNOLOGIES

SESSION ON FOCUSED TOPICS ADDRESSES CURRENT ISSUE RELATING
TO AEROSPACE BATTERIES - 1993 TOPIC CHARGE CONTROL FOR Ni-Cd
AND Ni-H₂ BATTERIES

BATTERY SYSTEMS TECHNOLOGY TASK

IMPEDANCE/NDE

The use of impedance spectroscopy as an interpretive tool for predicting cell performance, life, and quality is being investigated. The Lewis Research Center is responsible for this effort. To date Ni-Cd, Ni-H₂, and Li-SO₂ cells have been evaluated. Cells of the same chemistry exhibit characteristic impedance spectra that relate to manufacturer. It remains to be seen if these characteristics correlate with life and performance.



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IMPEDANCE NDE - LeRC

OBJECTIVE: INVESTIGATE THE USE OF IMPEDANCE SPECTROSCOPY
AS AN INTERPRETIVE TOOL FOR DETERMINING CELL
PERFORMANCE AND PREDICTING LIFE

VARIOUS CHEMISTRIES ARE UNDER INVESTIGATION
SUPER Ni-Cd CELLS
Ni-MH CELLS
IPV & BIPOLAR Ni-H₂ CELLS

BATTERY SYSTEMS TECHNOLOGY TASK

SECONDARY BATTERY TECHNOLOGY

The Secondary Battery Technology Task was established to improve the performance, quality, safety, and reliability of secondary battery systems. This task presently focuses on the nickel-cadmium and nickel-hydrogen systems which encompass the majority of NASA's present and planned secondary battery applications. Recommendations of the Battery Review Board are presently being implemented under this task area.

Presently, nickel-cadmium batteries provide the storage capability for the majority of NASA's missions. As a result, the future of nickel-cadmium manufacturing and the availability of nickel-cadmium cells are of major concern to the agency. NASA is in the process of evaluating nickel-cadmium cells from a variety of sources in an effort to ensure a supply of qualified cells for future NASA missions.

Ni-H₂ cell verification activities have also been expanded based on the recommendations of the Battery Review Board. The need for a program addressing nickel-metal-hydride development has been assessed, preliminary evaluation of the technology has been initiated.



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SECONDARY BATTERY TECHNOLOGY TASK

OBJECTIVE: IMPROVE PERFORMANCE, QUALITY, SAFETY AND
RELIABILITY OF SECONDARY BATTERY SYSTEMS

FOCUS ON Ni-Cd AND Ni-H₂ SYSTEMS - EXPAND TO INCLUDE Ni-MH

IMPLEMENT RECOMMENDATIONS OF BATTERY REVIEW BOARD

RESOLVE PROBLEMS WITH EXISTING Ni-Cd TECHNOLOGY

ABANDON NASA STANDARD CELL CONCEPT - IDENTIFY ALTERNATE
SOURCES OF Ni-Cd CELLS

FORMULATE POLICY REGARDING Ni-MH TECHNOLOGY

EVALUATE Ni-H₂ CELL DESIGN FEATURES

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM



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SECONDARY BATTERY TECHNOLOGY TASK

NICKEL- CADMIUM BATTERY TECHNOLOGY

NICKEL-HYDROGEN BATTERY TECHNOLOGY

NICKEL-METAL HYDRIDE BATTERY TECHNOLOGY

DEVELOPMENT OF DPA PROCEDURES

DEVELOPMENT OF SEPARATOR TEST PROCEDURES

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM

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VERIFICATION OF SECONDARY CELLS

In order to support flight programs and address NASA's future needs with respect to nickel-cadmium cells, the NASA Aerospace Flight Battery Systems Program has a subtask that involves the evaluation of current technology Ni-Cd cells from a variety of sources, including Gates Aerospace Batteries, Hughes, SAFT, Sanyo, and Acme.



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NICKEL-CADMIUM BATTERY TECHNOLOGY VERIFICATION OF SECONDARY CELLS

OBJECTIVE: PROVIDE INDEPENDENT VERIFICATION OF
MANUFACTURING FLIGHT CELLS BY PROCURING AND
TESTING REPRESENTATIVE CELLS FROM VARIOUS
MANUFACTURERS

GATES Ni-Cd CELLS - INTERACTIVE CONTRACT

ADVANCED Ni-Cd VERIFICATION
SUPER Ni-Cd & MAGNUM Ni-Cd

FOREIGN SOURCE EVALUATION
SAFT CELLS
SANYO CELLS

ALTERNATE SOURCE - ACME Ni-Cd CELLS

MISSION SPECIFIC SUPPORT - MO/TOPEX

SECONDARY BATTERY TECHNOLOGY TASK

NICKEL-CADMIUM CELL TEST STATUS

The testing of state-of the art Ni-Cd cells has been ongoing for several years. The status of the current tests on cells from Hughes, Gates and SAFT is summarized on the facing chart.



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NICKEL-CADMIUM CELL TEST STATUS

VENDOR	DESCRIPTION	CAP (AH)	# CELLS		CONDITIONS		STATUS CYCLES	FAILURES
			ORIG	LEFT	DOD (%)	TEMP (°C)		
HUGHES	ADVANCED NI-Cd - Z/PS	20	5	5	40	20	20400	RECONDITIONED @ 16K
HUGHES	ADVANCED NI-Cd - Z/PS	20	5	5	40	20	20300	
HUGHES	ADVANCED NI-Cd - PP/PBI	20	5	5	40	20	19700	
HUGHES	ADVANCED NI-Cd - Z/PBI	20	8	8	40	20	18600	
HUGHES	ADVANCED NI-Cd - Z/PS	20	8	8	25	30	18700	
HUGHES	ADVANCED NI-Cd - Z/PS	20	8	6	40	30	17700	
HUGHES	ADVANCED NI-Cd - Z/PS	20	8	8	40	20	18000	
HUGHES	SUPER NI-Cd - Z/PBI +ADD	20	8	8	40	20	18000	
SAFT		24	5	5	40	0	24400	STOPPED TESTING
SAFT	VOS B	20	5	5	40	20	20900	
SAFT	VOS A	24	5	5	40	20	24600	
SAFT		40	5	5	40	20	2400	
HUGHES	MO SUPER NI-CD CELLS	37	5	5	40	20	8200	
GATES	MO FLIGHT CELLS	42	5	5	40	20	10800	
GATES	TOPEX FLIGHT CELLS	50	4	4	40	20	6100	

10/93

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM

GATES INTERACTIVE CELL CONTRACT

Modifications to the present Gates cells are also being investigated as a part of nickel-cadmium cell verification activities. An interactive contract with Gates, under the management of the Lewis Research Center, allows for variations in the porosity, nickel attack level, and the loading level of the positive electrodes as well as the incorporation of alternate separators, and varied electrolyte levels. Modified cells will be constructed and tested to evaluate the effectiveness of the component changes. The composite Task Force Group on Near Term Nickel-Cadmium Cell Design has made recommendations regarding the selected parameters and levels to be evaluated. Plans are to initially evaluate the effects of nickel attack level, positive plate loading and negative plate loading in a statistically designed experiment. Cell construction has been delayed in order to accommodate recommended design changes to the negative electrode to address current problems associated with GRO and UARS satellites.



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NICKEL-CADMIUM BATTERY TECHNOLOGY VERIFICATION OF SECONDARY CELLS

GATES INTERACTIVE CELL CONTRACT - LeRC

CONTRACT TO PURCHASE CELLS WITH MODIFICATIONS TO
PLATES AND SEPARATORS - VERIFY DESIGN MODIFICATIONS TO
SOLVE PRESENT PROBLEMS

WORKING WITH COMPOSITE TASK FORCE GROUP ON NEAR
TERM CELL DESIGN

STATISTICALLY DESIGNED EXPERIMENT EVALUATING NICKEL
ATTACK, POSITIVE LOADING AND NEGATIVE LOADING HAS
BEEN FORMULATED

CELL DESIGN PARAMETERS HAVE BEEN MODIFIED TO REFLECT
RECOMMENDATIONS OF "BATTERY TECHNOLOGY STEERING
GROUP"

SECONDARY BATTERY TECHNOLOGY TASK

EXPANSION OF MANUFACTURER VERIFICATION TESTING

In addition to the on-going testing on cells from Gates, Hughes and SAFT, cells from Sanyo, Acme, Eagle Picher and additional cells from SAFT have been ordered to expand cell verification activities per the recommendation of the Battery Review Board. The expansion of the cell verification activities is outlined here.



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NICKEL-CADMIUM BATTERY TECHNOLOGY VERIFICATION OF SECONDARY CELLS

EXPANSION OF CELL VERIFICATION ACTIVITIES

FOREIGN CELL EVALUATION - LeRC

SANYO CELLS	25, 35 AH CELLS ON TEST ATP COMPLETED
SAFT CELLS	21, 50 AH CELLS ON ORDER

ADVANCED Ni-Cd EVALUATION - LeRC, GSFC

SUPER Ni-Cd CELLS	25, 21 AH CELLS ON ORDER 10, 50 AH CELLS TO BE TESTED
MAGNUM Ni-Cd CELLS	25, 21 AH CELLS ON ORDER

ALTERNATE SOURCE CELL EVALUATION - LeRC

ACME CELLS	12 EA 18 & 55AH CELLS NYLON & PP SEPARATORS
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SECONDARY BATTERY TECHNOLOGY TASK

VERIFICATION TEST PLAN

Cells are being procured in groups of 20-25 and being evaluated according to the plan outlined here. The verification test plan is summarized on the following two charts.



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NICKEL-CADMIUM CELL VERIFICATION

PROPOSED VERIFICATION TEST PLAN

REPEAT PORTIONS OF MANUFACTURERS INSPECTION/ACCEPTANCE TESTS

RUN NASA STANDARD ACCEPTANCE TEST PROCEDURE FOR INFORMATION ONLY

PERFORM LIFE CYCLE TESTING

FOR 20 CELLS FROM SAME LOT (MINIMUM):

1 PACK	PERFORM V/T CHARACTERIZATION FOLLOWED BY ACCELERATED GEO
3 PACKS	LEO REGIME @ VARIOUS TEMPERATURES

FOR 25 CELLS FROM SAME LOT (MINIMUM):

1 PACK	PERFORM V/T CHARACTERIZATION
1 PACK	ACCELERATED GEO
3 PACKS	LEO REGIME @ VARIOUS TEMPERATURES

SECONDARY BATTERY TECHNOLOGY TASK



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NICKEL-CADMIUM CELL VERIFICATION

PROPOSED LIFE CYCLE TEST REGIMES FOR Ni-Cd CELL EVALUATION
PACKS OF 5 CELLS EACH

TEST/ PACK	DESCRIPTION	DOD (%)	TEMP (°C)	DETAILS OF REGIME
1	V/T CHARACTERIZATION - SHOCK/VIBRATION			V/T CHARACTERIZATION - PROCEDURE TBD
2	STANDARD STRESS TEST	40	20	CHARGE - 1 HR, 0.8C TO V/T LIMIT, TAPER DISCHARGE - 0.8C FOR 30 MINUTES - TO 40% DOD
3	HIGH TEMPERATURE STRESS TEST	40	30	CHARGE - 0.8C TO V/T LIMIT, TAPER DISCHARGE - 0.8C FOR 30 MINUTES - TO 40% DOD
4	LOW TEMPERATURE STRESS TEST	40	0	CHARGE - 0.8C TO V/T LIMIT, TAPER DISCHARGE - 0.8C FOR 30 MINUTES - TO 40% DOD
5	ACCELERATED GEO	80	10	2 WEEK SUN PERIODS/RECONDITIONING TRD

PLAN REQUIRES MINIMUM OF 25 CELLS - IF ONLY 20 CELLS ARE AVAILABLE - THE SAME PACK WILL BE USED FOR
TESTS 1 AND 5.

SECONDARY BATTERY TECHNOLOGY TASK

MISSION RELATED CELL VERIFICATION

Stress testing of packs of cells representing the flight lots and mission simulation testing of cells for Mars Observer and Topex are other ongoing cell verification activities.



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NICKEL-CADMIUM BATTERY TECHNOLOGY VERIFICATION OF SECONDARY CELLS

MISSION RELATED CELL VERIFICATION

MARS OBSERVER - JPL

42 AH NASA STANDARD GATES CELLS SUPER Ni-Cd CELLS STRESS TEST,
MISSION SIMULATION TEST

TOPEX - JPL

50 AH NASA STANDARD CELLS - STRESS TEST & MISSION SIMULATION
TEST

BATTERY TEST BED - JPL

MISSION SUPPORT - GRO, UARS ETC.

MANAGE DIVERGENT CELLS/BATTERIES - FACILITY SIMULATE MPS POWER
SYSTEM

SECONDARY BATTERY TECHNOLOGY TASK

APPLIED NICKEL-CADMIUM TECHNOLOGY TASK

The Jet Propulsion Laboratory is responsible for the Applied Nickel-Cadmium Technology subtask. This subtask involves the development of an electrochemical model of the nickel-cadmium system that involves physical, chemical, and electrochemical studies at the component and cell levels. The model will be used to develop an accelerated test which can be used to determine the quality and reliability of flight lot cells without extensive life testing and to predict the performance of a battery from a set of spacecraft operating conditions. Phase I of the model, which involves using a table lookup approach for determining cell performance, has been implemented and made available for distribution through COSMIC. Phase II of the model involves the replacement of the table lookup approach used in Phase I with a one dimensional electrochemical model, developed under a contract with Texas A&M. The model, simulating the charge and discharge has been developed. The model predictions match actual test data through much of the cycle life. The third and final phase of the model involves the expansion to a two dimensional model and the incorporation of factors to predict performance degradation. The modeled is scheduled for completion this fiscal year.



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NICKEL-CADMIUM BATTERY TECHNOLOGY APPLIED NICKEL-CADMIUM TECHNOLOGY - JPL

OBJECTIVE: DEVELOPMENT OF PERFORMANCE MODEL FOR
PREDICTION OF BATTERY PERFORMANCE UNDER
SPECIFIED SPACECRAFT OPERATIONAL CONDITIONS

PHASE I LOOKUP TABLE FOR PREDICTING PERFORMANCE /
VOLTAGE AND EFFICIENCY VS TEMPERATURE AND
STATE-OF-CHARGE

PHASE II DEVELOPMENT OF ONE DIMENSIONAL
ELECTROCHEMICAL MODEL TO REPLACE LOOKUP
TABLES

PHASE III EXPAND PHASE II - INCORPORATE DEGRADATION INTO
PERFORMANCE MODEL

SECONDARY BATTERY TECHNOLOGY TASK



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NICKEL-CADMIUM BATTERY TECHNOLOGY APPLIED NICKEL-CADMIUM TECHNOLOGY - JPL

Ni-Cd MODEL STATUS

FINAL STAGES OF DEVELOPMENT - OPTIMIZATION

COMPARE PREDICTIONS WITH ACTUAL PERFORMANCE DATA

MODIFICATIONS TO TREATMENT OF POSITIVE ACTIVE MATERIAL

SCHEDULED FOR COMPLETION THIS FISCAL YEAR

SECONDARY BATTERY TECHNOLOGY TASK

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NICKEL-HYDROGEN TECHNOLOGY

The major goal of the Nickel-Hydrogen Technology subtask is to evaluate design features for incorporation into nickel-hydrogen cells for NASA missions. Steps are underway to evaluate the critical aspects of nickel-hydrogen technology in order to prevent a situation similar to that presently being experienced with nickel-cadmium cells and to ensure the consistent production of quality cells. The Lewis Research Center has responsibility for the Nickel-Hydrogen Technology subtask. Currently, the effects of the NASA advanced design features and the effects of 26% vs 31% KOH, cell design variations including stacking arrangements and impregnation processes are being evaluated in flight cells being tested at Crane.



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NICKEL-HYDROGEN BATTERY TECHNOLOGY CELL COMPONENT AND DESIGN EVALUATION - LeRC

OBJECTIVE: PROVIDE INDEPENDENT VERIFICATION OF DESIGN AND
COMPONENT VARIATIONS TO MANUFACTURING FLIGHT
CELLS BY PROCURING AND TESTING REPRESENTATIVE
CELLS FROM VARIOUS MANUFACTURES

VERIFICATION OF 26% KOH
CELLS FROM HUGHES, EP, GATES, YARDNEY

EVALUATION OF DESIGN FEATURES
CATALYZED WALL WICK
CELL STACKING

EVALUATION OF CELL COMPONENTS
NICKEL ELECTRODE IMPREGNATION PROCESS
SEPARATOR

SECONDARY BATTERY TECHNOLOGY TASK

NICKEL-HYDROGEN CELL TEST STATUS

The testing of various design features for Ni-H₂ cells has been ongoing for several years. The status of the current tests on cells is summarized on the facing chart.



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NICKEL-HYDROGEN CELL TEST STATUS

VENDOR	DESCRIPTION	CAP (AH)	# CELLS		CONDITIONS		STATUS CYCLES	FAILURES
			ORIG	LEFT	DOD (%)	TEMP (oC)		
HUGHES	26% KOH - AF STANDARD	50	3	0	80	10	-	15314,19500,23700
HUGHES	31% KOH - AF STANDARD	50	3	0	80	10	-	3729,4165,11355
EPI	NASA ADV DESIGN w/CAT WW	125	3	3	60	10	25400	
EPI	NASA ADV DESIGN w/o CAT WW	125	3	0	60	10	-	9588,13900,20575
GATES	26% KOH	65	5	5	60	10	8585	
GATES	31% KOH	65	5	5	60	10	8585	
EPI	26% KOH - AQUEOUS	65	3	3	60	10	8490	
EPI	31% KOH - AQUEOUS	65	3	3	60	10	8490	
EPI	26% KOH - ALCOHOLIC	65	3	3	60	10	8490	
EPI	31% KOH - ALCOHOLIC	65	3	3	60	10	8490	
EPI	BTB DESIGN w/CAT WW	65	3	3	60	10	6315	
EPI	RECIRCULATION	65	3	3	60	10	6315	
YTP	26% KOH	56	3	3	60	10	5700	
YTP	31% KOH	56	3	3	60	10	5700	
EPI	PE FILM/PE PAPER	50	3	0	60	10	0	LOW CAPACITY - NO LEO
EPI	PE FILM/PP FELT	50	3	0	60	10	0	LOW CAPACITY - NO LEO
EPI	ASBESTOS	50	3	0	60	10	-	2309,2309,2756
EPI	PE FILM/ZIRCAR	50	3	0	60	10	-	ALL @ -6700

11/4/93

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM

CPV BATTERY EVALUATION

Based on a recommendation made by the Battery Review Board, cell verification activities have been expanded to include CPV nickel-cadmium batteries. Batteries from Eagle Picher and Johnson Controls have been ordered.



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NICKEL-HYDROGEN BATTERY TECHNOLOGY CPV BATTERY EVALUATION - LeRC

OBJECTIVE: EVALUATE POTENTIAL OF EMERGING CPV TECHNOLOGY
TO MEET NASA'S FUTURE NEEDS

JOHNSON CONTROLS

28 VOLT, 50 AH BATTERY - DELIVERY JULY '94

EAGLE PICHER

2 CELL, 10AH CPV BATTERIES - ON ORDER
DELIVERY 9/94

SECONDARY BATTERY TECHNOLOGY TASK

NICKEL-HYDROGEN MODEL

JPL is responsible for developing a computer model for nickel-hydrogen batteries that parallels the work done on the nickel-cadmium model. The electrochemical model that will serve as the core for the cell model is being developed for the Office of Research and Development at the University of South Carolina.



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NICKEL-HYDROGEN BATTERY TECHNOLOGY NICKEL-HYDROGEN MODEL - JPL

**OBJECTIVE - DEVELOP A COMPUTER MODEL CAPABLE OF PREDICTION
ORBITAL PERFORMANCE OF A NICKEL-HYDROGEN
BATTERY USING A CELL LEVEL ELECTROCHEMICAL
MODEL BASED ON FUNDAMENTAL PHENOMENA**

**ELECTROCHEMICAL MODEL BEING DEVELOPED AT UNIVERSITY OF
SOUTH CAROLINA - JOE STOCKEL SUPPORT**

DEVELOPMENT WILL PARALLEL THAT OF THE Ni-Cd MODEL

SECONDARY BATTERY TECHNOLOGY TASK

DEVELOPMENT OF A STRESS TEST FOR NICKEL- HYDROGEN CELLS

The Marshall Space Flight Center is responsible for the task defining the conditions for a nickel-hydrogen stress test similar to the 40%DOD, 20 °C test currently used for Ni-Cd cells. Available data is being analyzed and conditions for defining the stress test are being established.



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NICKEL-HYDROGEN BATTERY TECHNOLOGY DEVELOPMENT OF Ni-H₂ STRESS TEST - MSFC

OBJECTIVE:

DEFINE AND VERIFY A STRESS TEST FOR NICKEL-HYDROGEN, COMPARABLE TO THE 40% DOD, 20°C TEST FOR NICKEL-CADMIUM CELLS

AVAILABLE LIFE TEST DATA EVALUATED

STRESS PARAMETERS HAVE BEEN IDENTIFIED

MATRIX HAS BEEN PROPOSED

SECONDARY BATTERY TECHNOLOGY TASK

ESTABLISHMENT OF STANDARD DPA PROCEDURES

The Marshall Space Flight Center has the responsibility for developing and establishing guidelines for NASA for the performance of destructive physical analyses for Ni-Cd and Ni-H₂ chemistries. Current DPA procedures used in the industry are being evaluated in an effort to identify a standard procedure for the agency. Drafts of the guidelines documents have been prepared.



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DEVELOPMENT OF DPA TEST PROCEDURES - MSFC

OBJECTIVE: DEFINE GENERAL GUIDELINES TO BE FOLLOWED BY FACILITIES
PERFORMING DPA PROCEDURES ON NICKEL-CADMIUM AND
NICKEL-HYDROGEN CELLS

AVAILABLE PROCEDURES HAVE BEEN EVALUATED

DRAFT GUIDELINES DOCUMENTS HAVE BEEN PREPARED

SECONDARY BATTERY TECHNOLOGY TASK

SEPARATOR TEST PROCEDURES TASK

The Lewis Research Center is involved in defining improved tests that will more closely evaluate separator characteristics as related to the actual cell environment. Detailed procedures are being developed. Publication of a document containing the recommended test procedures is expected by the end of the fiscal year.



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DEVELOPMENT OF SEPARATOR TEST PROCEDURES - LeRC

OBJECTIVE: DESIGN AND DEVELOPMENT OF UNIFORM RELIABLE TEST
PROCEDURES FOR EVALUATING CANDIDATE SEPARATOR
MATERIALS FOR Ni-Cd, Ni-H₂ & Ni-MH CELLS

RECOMMENDATIONS REGARDING TEST PROCEDURES - DETAILED
PROCEDURES BEING DEVELOPED

ACCEPTANCE CRITERIA

PUBLICATION BY END OF FISCAL YEAR

SECONDARY BATTERY TECHNOLOGY TASK

NICKEL-METAL HYDRIDE TECHNOLOGY

The Battery Program funded a task at JPL to assess the status of nickel-metal hydride technology for aerospace applications. The survey has been completed and the present approach is to perform preliminary evaluations of aerospace cells from any available sources.



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NICKEL-METAL HYDRIDE TECHNOLOGY

NICKEL-METAL HYDRIDE TECHNOLOGY ASSESSMENT - JPL

DETERMINE STATUS OF Ni-MH TECHNOLOGY AND ASSESS
POTENTIAL FOR USE IN NASA LEO, GEO AND PLANETARY MISSIONS

NICKEL-METAL HYDRIDE TECHNOLOGY EVALUATION - GSFC, JPL, LeRC

COORDINATED EFFORT - PROCUREMENT AND TESTING OF
AEROSPACE DESIGN CELLS

SECONDARY BATTERY TECHNOLOGY TASK

PRIMARY BATTERY TECHNOLOGY

The objective of the Primary Battery Technology Task is to improve the performance, reliability and safety of primary battery systems. The major thrust of this effort is to reduce the number of different cell chemistries now used by identifying and qualifying high performance NASA Standard Primary Cells. The Johnson Space Center has primary responsibility for work performed in the primary battery area.



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PRIMARY BATTERY TECHNOLOGY TASK

OBJECTIVE:

IMPROVE PERFORMANCE, QUALITY, SAFETY AND
RELIABILITY OF PRIMARY BATTERY SYSTEMS

REDUCE NUMBER OF CHEMISTRIES USED IN PRIMARY
CELL APPLICATIONS

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM



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PRIMARY BATTERY TECHNOLOGY TASK

SHORT CIRCUIT PROTECTION

LITHIUM D- CELL DEVELOPMENT

DEVELOPMENT OF ZN-AIR CELL

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SHORT CIRCUIT PROTECTION

JSC contracted with Yardney Technical Products to investigate the development of internal/external short circuit protection for lithium cells. The objective of this subtask was to develop a positive control for both internal and external short circuits in lithium cells. The control is activated by temperature, shutting the cells down from the heat generated by shorts. The protective coating developed under this contract was so thick (~25 mils) that the capacity was reduced by 50% and the rate capability was also substantially reduced. Alternate concepts are under evaluation.



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NASA PRIMARY BATTERY - JSC

DEVELOPMENT OF INTERNAL/EXTERNAL SHORT CIRCUIT PROTECTION FOR LITHIUM CELLS

POSITIVE CONTROL (COMPOSITE THERMAL SWITCH) INCORPORATED
INTO CATHODE FOR INTERNAL/EXTERNAL SHORT CIRCUIT
PROTECTION

FILM DEVELOPED - TOO THICK, RESULTING IN LOSS OF CAPACITY
AND RATE CAPABILITY

ALTERNATE CONCEPTS ARE UNDER INVESTIGATION

PRIMARY BATTERY TECHNOLOGY TASK

LITHIUM D-CELL DEVELOPMENT

Lithium D-Cell development encompasses the development of an optimized lithium D-cell, or a family of D-cells, that can serve as a building block for the for the varied applications now flying and those to be flown in the near future. The goal is to develop cells capable of meeting relatively high rate requirements while being as tolerant as possible to electrical and thermal abuse. The candidates evaluated include the JSC Li-BCX, the JPL high rate LiSOCl_2 , and the Wilson Greatbatch, Ltd. Li-CSC. The WGL cell was recommended, however there are concerns with its short and abuse tolerance. Present efforts involve qualification of separate cells for high and low rate applications. con



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NASA PRIMARY BATTERY - JSC

LiSOCl_2 D CELL DEVELOPMENT

EVALUATION OF JPL HIGH RATE LiSOCl_2 D, JSC LiBCX AND WILSON GREATBATCH LiCSC TO IDENTIFY OPTIMUM CELL CONFIGURATION - COMPLETED

WGL CELL RECOMMENDED - CONCERNS WITH SHORT AND ABUSE TOLERANCE

PROPOSED FOLLOW-ON ENGINEERING AND QUAL OF LOW TO MODERATE RATE CELL

PRIMARY BATTERY TECHNOLOGY TASK

ZINC-AIR DEVELOPMENT

The NASA Aerospace Flight Battery Systems Program also supports the development of a pair of Zn-O₂ cells. A high capacity cell of 200 AH at rates of 25-100 hours is under investigation. A low capacity, high rate cell has been successfully developed.



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NASA PRIMARY BATTERY - JSC

DEVELOPMENT OF Zn-O₂ CELL

DEVELOPMENT OF LARGE CAPACITY LOW RATE AND LOW CAPACITY, HIGH RATE CELL/BATTERY DESIGNS FOR SHUTTLE ORBITER APPLICATIONS

HIGH CAPACITY CELL UNDER EVALUATION
200 AH, 25-100 HR RATES

LOW CAPACITY, HIGH RATE CELL SUCCESSFULLY DEVELOPED
20 AH, 3 AMP RATE -160 WH/#

EMPIRICAL PERFORMANCE MODEL AND THEORETICAL MATH MODEL
HAVE BEEN DELIVERED

ALTERNATE WCCS BATTERY - 6 VOLTS, 13 AH DEVELOPED -
UNDERGOING QUAL TESTING AT JSC

PRIMARY BATTERY TECHNOLOGY TASK

SUMMARY REMARKS

The NASA Aerospace Flight Battery Systems Program provides for a balanced cell, battery and systems program which includes primary and secondary battery activities in support of NASA's flight programs. It has provided for increased communication within the agency and with the battery industry as well. The program addresses flight battery and related flight power system activities which are essential for ensuring safe and reliable performance. Based on recommendations made by the Battery Review Board following an investigation of the aerospace battery industry as it pertains to NASA, the program has undergone considerable redirection over the past year.



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SUMMARY REMARKS

PROGRAM HAS UNDERGONE REDIRECTION BASED ON BATTERY REVIEW BOARD RECOMMENDATIONS

EMPHASIS IS ON SECONDARY BATTERY SYSTEMS - VERIFICATION OF TECHNOLOGIES FOR FLIGHT APPLICATIONS

BATTERY PROGRAM HAS RESULTED IN INCREASED COMMUNICATION AND COOPERATION AMONG NASA CENTERS AND WITHIN THE AEROSPACE BATTERY COMMUNITY

THE PROGRAM ADDRESSES FLIGHT BATTERY ISSUES RELATING TO NASA'S FLIGHT PROGRAMS

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM

